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"A Review on Design & Analysis of Disk Brake Rotor for Maximum Heat Transfer Using Finite Element Method"

Pranay Dawne [1], Ruchika Saini [2],

1.Research Scholar, Department of Mechanical Engineering, JEC Jabalpur (M.P.)
2. Assistant Professor, Department of Mechanical Engineering, JEC Jabalpur (M.P.)

Abstract

In this paper a brief review of thermal analysis of Disk brake rotor for various materials and design patterns has been addressed. Disk Brakes provide better stopping performance and are safer and cost efficient at the same time. However drum brakes provide better performance when it comes to heavy duty vehicle. Among various kinds of braking systems, Disk brakes are widely used across different segments of road vehicles, whether it is gasoline based or electric based, because of their light weight setup, comparatively low cost and flexibility to use with other types of braking systems such as with drum breaks or with ABS which is an electronic braking system. Due to this fact there are several applications of Disk brakes which are studied and developed. The various researchers has been studying the cooling performance of the Disk brakes in order to get results showing faster way to dissipate heat which will ultimately improve its durability and makes it safer under braking condition.

The aim of this paper is "To analyze the heat generation and dissipation of the rotor to obtain more optimized materials and design in order to prevent its failure under constant mechanical and thermal load".

Keywords: Disk brake rotor analysis, finite element analysis, design and analysis etc.

INTRODUCTION

The disk brakes are a two parts system, One being the rotating plate called the Disk and the other being the caliper assembly which is clamped on the periphery of the rotor which has a friction material. When the caliper is pressed against the rotating Disk, causes the generation of heat, converting kinetic energy of the rotor is high speed into heat energy which gets accumulated in the rotating Disk. So if the pressure applied by the caliper on the rotor is large, then the heat generated in the rotor is large. The action of caliper to press against the rotating Disk is made possible by implementing one or more hydraulic pistons. Thus the design of the Disk brake rotor is based on some of the crucial factors such as heat generation, heat dissipation, mechanical loading etc.

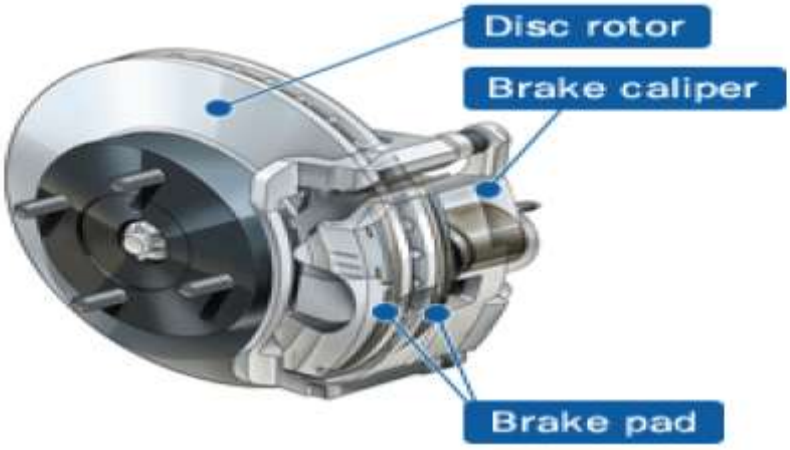

Figure.1 Disc brake and components.

The main components of a Disk brake are:-

1. Rotating Disk/Disk rotor.
2. Brake Pads.
3. Caliper assembly.

Brake rotor is an important component in the Disk brake type braking system that plays a crucial role in stopping the vehicle. This is because the rotor is the component on which the break pad, clamps to creating friction between the two ultimately causing the vehicle to stop. This is why brake rotor is as important as the brake pad. Like the other Disk brake components there are different types of brake rotors available to choose from as follows:-

There are mainly 2 types of Disk rotors based on the surface area of the Disk rotor.

1. Vented -This one has two Disks or rotor connected to each other via vents and thus this one has a larger surface area.
2. Non-Vented-This one has just a single Disk having relatively smaller surface area.

Also, there are different types of Disk rotors depending on performance required and the amount of Disk heat to dissipate. Essentially, these are of 4 kinds as follows

1. **Normal Disk rotor:** These are the standard plain faced Disk rotors and are generally equipped in a vehicle. These have the largest amount of surface area in contact with the brake pads and as a result these have the best braking performance as far as break power is concerned. Although, as there is not a lot of passage for the built up heat to escape from the rotor thus its performance for heat dissipation is poor and causes break fade and pad glazing.
2. **Drilled Disk rotor:** The holes are drilled on the surface of a rotor. This provides a passage for the heat to escape from the rotors, for the gasses to escape which were produced due to friction between pad and rotor and for the water to run out of the rotors when the vehicle runs through pot holes during rainy weather. In this way these types of rotors provide a better overall performance.

3. **Grooved Disk rotor:** As the name suggests these have contours grooved on the flat surface of the rotor. These grooves allow the dusts, gasses, and water to travel away from the braking surface which improves the performance of the rotor for heat dissipation. This keeps the pad face fresh allowing better breaking. But because of the grooves the braking process becomes louder due to scrubbing of the pads on the rotor face. This wears down the break pad quickly.
4. **Miscellaneous type:** These cannot be classifies in any categories but are also commonly used:
    - Bicycle brake rotor
    - Motorcycle brake rotor
    - Truck brake rotor
    - Performance brake rotor
    - Combined brake rotor

Along with the type of Disk rotor to use, the material of which it is made of also has a big impact on braking performance such as wear and tear, heat conduction, maximum stress in cyclic loading etc. The most common type of materials used in commercial manufacturing of brakes is grey cast iron. In some cases ceramic materials are also used.

Literature Review

Pandya Nakul Amrish et al; The purpose of this research is to analyze different types of disc brake rotors, which are commonly used in automobile industry and to propose a new design of brake rotor. Analysis of brake rotor includes Structural analysis and Steady state Thermal analysis for each design. A comparison between the existing brake rotors and proposed new design is carried out and based on the results the best design is found out by ANSYS software [1].

Figure.2 (a) Normal disc rotor.

Figure.2 (b) Drilled disc rotor.

S.S.Kang and S.K.Cho et al; In this Research to analyze geometry of vents is motorcycle Disk brake which affect the surface of the Disk. To analyze the thermal characteristics of disc brakes, thermal deformation analysis and thermal stress analysis due to heat transfer was carried out through finite element analysis for ventilated disk and solid disk rotors. For 3 dimensional modeling and finite element analysis of the disks, the commercial code ANSYS is used. On completing the analysis they found out that during the cooling process the maximum temperature of the ventilated disks decreases based on the increase of heat dissipation area due to the vent and as little as 2.5%, even as much as

4%, decreased depending on the diameter of the vent, compared with that of the solid disks. The thermal deformation is ventilated type of disk rotor occurs in all directions by 0.1162mm, the thermal distribution in circumferential direction showed large deviation, about 0.017 mm, due to the vents. Stresses caused by heat were focused on the mounting area (hub) and vent (flange) of the ventilated disk [2].

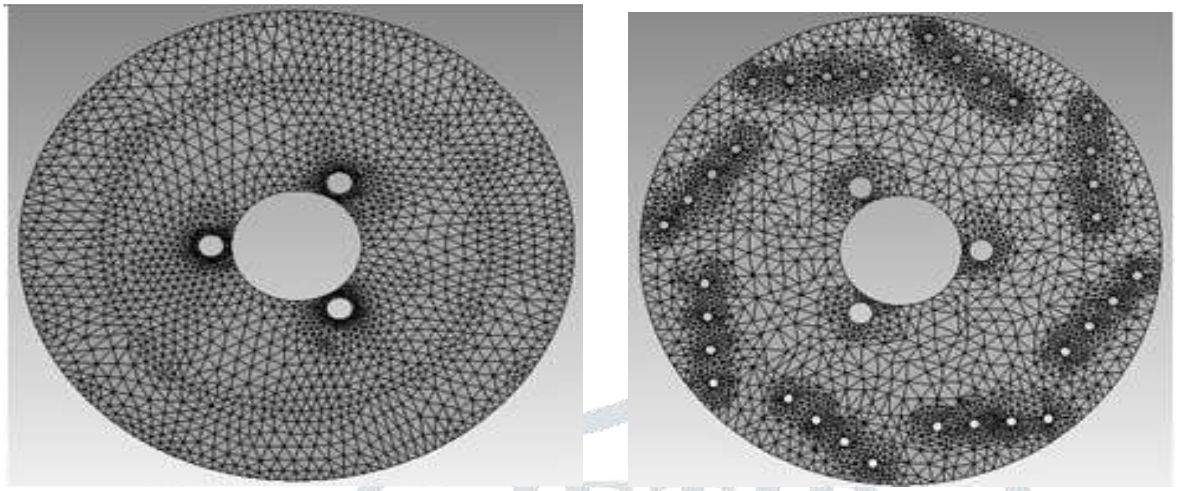

Figure.3 Finite element meshes for models of disks.

Zhang Jian and Xia Changgao et al; This paper proposed that according to the real dimension of the braking disk, the finite element modeling for 3-d transient cyclic symmetry during the long downhill braking is established. The distribution of the transient temperature field of the rotor during the braking are analyzed. The variation of the friction factor combined with the temperature characteristics of the friction factor during the braking are analyzed. The analysis result shows that during the braking the the temperature of the brake rises increasingly and reaches the highest temperature of 316.04 degrees Celsius at the end of braking, the high temperature section concentrates in the far area of the rotor. The changes in the friction factor is relatively stable during the long downhill breaking and there is no obvious thermal recession. By the analysis of distribution of transient temperature field of brake disc under long downhill braking condition, it is obtained that the density of the heat flux increases with the increasing friction radius. Temperature gradient in the radial direction is higher. Thermal conduction and convection are enough. Temperature gradient in the axial direction is almost uniform [3].

A.Belhocine and M.Bouchetara et al; Proposed the study to analyze the thermo-chemical behavior of dry contact between the Disc rotor and the pad during the braking phase and simulated it in ANSYS 11. They used the transient temperature model to identify the factor of geometric design of the disc to install the ventilated rotors in the vehicles. The thermo-structural analysis is then used with coupling to calculate the deformation obtained and Von Misesstresses in the rotor and the contact pressure in the pad. It is found out the ventilation system plays a crucial role in cooling the rotor and provides a good high resistance. The analysis showed that the temperature field and the stress field during the braking process is fully coupled. The temperature, Von Misesstress and total deformation is increased beacuase the thermal stresses are additional to mechanical stresses which causes the crack propagation and fracture and wears of the disc and pads [4].

Bangaru Bharath Kumar et al; carried out in this research to analyze a slotted disc brake commonly used in motorsport and luxury automobiles. The main purpose of the study id to analyze the thermal behavior of the dry contact between brake disk and the break pads and shows the result by comparing brake rotor materials of cast iron and stainless steel. The brake disk rotor was analyzed for thermal spikes usinf analytical calculations and finite element analysis. For the same heat flux heat generated by grey cat iron is lower than stainless steel and concluded that grey cast iron is more suitable for the manufacturing of disc rotors. But grey cast iron get easily corroded when comes in contact with water and moisture so stainless steel can also be used in turn [5].

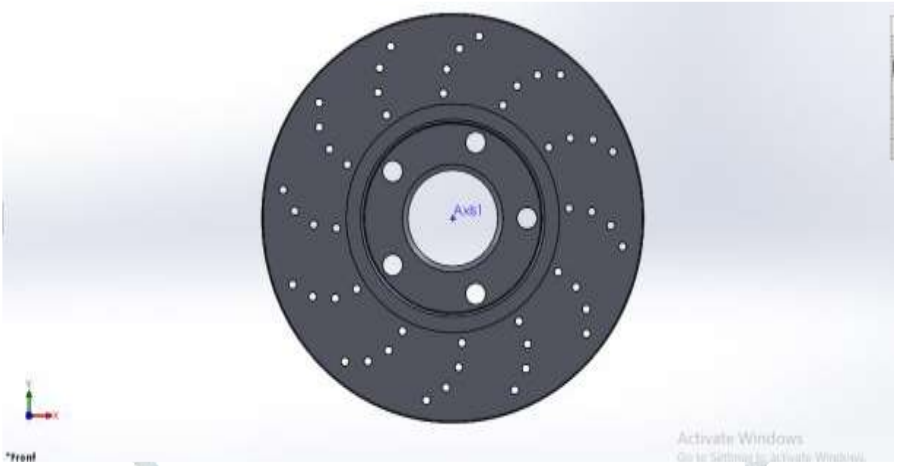

Figure.4 Schematic diagram for modelling of disc brake

Tanuj Joshi and Sarang Kaul et al; carried out the research to propose a new type of brake rotor to be used in sports bike in order to improve the braking performance by increasing the maximum deceleration and in turn reducing the distance in which the vehicle come into complete halt. Also this study compares the performance of the proposed rotor with the more conventional type of rotors used is day to day used vehicles. For this they proposed a Perimetric design for brake rotor. The Perimetric disc rotors are more recently introduced type of rotors. It is a brake rotor mounted on the outer rim of the wheel so for the same applied force the brake force generated is much more significant and thus in turn produces larger braking torque. Such result is obtained because the area in contact is much more as compared to the conventional type of brake rotors. The analysis concluded that the torsional strength for maximum Von Mises Stresses of perimetric type rotors is comparable to the conventional type of rotors. For lateral strength simulation maximum value of Von Mises stresses is about half in the perimetric rotors when compared to the conventional rotors and maximum stress induced are much lower in both cases. Also the maximum residual stresses induced due to temperature distribution is lower than the yield stress in perimetric rotors [6].

M.H. Pranta et at; In this study to modified ventilated disk brake rotor has been developed with curved vents, holes, and slots and analyzes the stress and temperature distribution. Finite element models of the rotor are shaped with SolidWorks and simulated using ANSYS. Structural and thermal characteristics are compared with a reference disk brake rotor. It is found that the proposed rotors outperformed the conventional one in terms of stress generation, temperature distribution, and factor of safety. Furthermore, computation has been done to find out the bestsuitedmaterial for one of the proposed designs. The result provides a physical insight of the structural and thermal characteristics of the geometrically modified rotor that can be implemented in the automotive industry [7].

Challa Balaji Naga Sai Abhishikt et al; In this paper analysing the disc rotor and brake pads design and material while counting other impacting factors contribute to braking efficiency. The friction coefficient is abate by the brake disc's overheat and to circumvent this issue, and the rotor disc should be adequately ventilated to allow maximum heat dissipation from the disc to the surroundings. The overheating of the disc rotor causes the surface to harden, making the brake pads challenging to seize them. By subsuming drilled contours on the rotor disc, the enhanced surface area aids in the rapid heat transfer from the rotor disc to the environment moderating the heat generated at the pad-disc interface. Anew drafted brake rotor discs with drilled contour and ventilated discs are model using SOLIDWORKS. Static structural and thermal analysis performed with different disc materials using the finite element simulation software ANSYS. Based upon the temperature gradient, the heat dissipation obtained from the study, it is evident that the newly designed discs are significantly efficient, with longer brake spans and no abundant reduction in coefficient of friction of brake pads. A comparative study stated out for the various materials of the disc rotor [8].

Figure.5 (a) Isometric view of drilled contour disc rotor. Figure.5 (b) Isometric view of ventilated disc rotor.

Vishvajeet et al; In this study carried out the during operation brake disk subjected to thermal and frictional loading, when disk pad squeeze the rotor disk. This thermal loading decreases the performance of disk brake. So it is important to find the best suited material, which can maintain the heat generation and sustain the other mechanical loading. The objective of present study is to find out best suited material on the basis of thermo-mechanical analysis. A CAD model of brake disk was designed on Catia and analyzed by Ansys. The model was simulated for four different materials and results were compared on the basis of total deformation, Stress and thermal behaviour of material [9].

CONCLUSION

The whole work done by the researchers, they used various method for the disc rotor and brake pads design and material while counting other impacting factors contribute to braking efficiency the rotor disc should be adequately ventilated to allow maximum heat dissipation from the disc to the surroundings. The overheating of the disc rotor causes the surface to harden. The enhanced surface area aids in the rapid heat transfer from the rotor disc to the environment moderating the heat generated at the pad-disc interface. Anew drafted brake rotor discs with drilled contour and ventilated discs are designed. Static structural and thermal analysis performed with different disc

materials using the finite element simulation software. Based upon the temperature gradient, the heat dissipation obtained from the study, it is evident that the newly designed discs are significantly efficient with longer brake spans and no abundant reduction in coefficient of friction of brake pads. A comparative study stated out for the various materials of the disc rotor. They are mostly used different designs on the brake pads which increase the maximum heat transfer and induced the high friction between the disc rotor and brake pads in the disc brake. A drafted brake rotor discs gives more heat transfer over the rotor disc. The different types of brake pads design provided on the disc rotor which increases heat transfer and efficiency of the brake as compared to the normal brake. In this case, it is a research gap to carry out the investigate the maximum heat dissipation from the disc brake. And the heat transfer phenomena can enhance by using the different design in the brake pads. The further research can be gone in this direction.

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